LIGHT DIFFUSING PLATE, OPTICAL ELEMENT, AND LIQUID-CRYSTAL DISPLAY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a light diffusing plate which has anisotropy in the scattering of linearly polarized light, is highly effective in diffusing the directions of the scattering thereof, and is suitable for use in, e.g., improving the perceptibility, brightness, and other performances of liquid-crystal displays and the like. This invention further relates to an optical element employing the light diffusing plate.

The present application is based on Japanese Patent Application No. Hei. 10-376394 which is incorporated herein by reference.

2. Description of the Related Art

Conventionally known light diffusing plates which comprise a matrix and, dispersedly contained therein, regions having anisotropy in refractive index and which are anisotropic with respect to the scattering of linearly polarized light include a diffusing plate comprising a combination of a thermoplastic resin and a low-molecular liquid crystal, one comprising a combination of a low-molecular liquid crystal and a photocrosslinkable low-molecular liquid crystal, and one comprising a combination of poly(vinyl alcohol) and a low-

molecular liquid crystal (see U.S. Patent 2,123,901, WO 87/01822, EP 0506176, and JP-A-9-274108). (The term "JP-A" as used herein means an "unexamined published Japanese patent application".)

The above light diffusing plates are intended, for example, to supply linearly polarized light in such a state as not to be readily absorbed by a polarizing plate to thereby reduce absorption loss and thus improve the brightness of liquid-crystal displays. Such light diffusing plates may be expected to eliminate problems of a conventional system for absorption loss reduction comprising a cholesteric liquid-crystal layer and a quarter-wavelength plate. These problems are that the large wavelength dependence of the cholesteric liquid crystal causes coloration of, in particular, oblique transmitted light, and that the conventional system is inapplicable to reflection type liquid-crystal displays or the like.

However, the conventional light diffusing plates described above are unsuitable for practical use, for example, because they are difficult to produce and because when applied to liquid-crystal displays or the like, the diffusing plates have poor handleability and poor stability of functions.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a light diffusing plate which is easily producible and excellent in thermal and chemical stability and suitability for practical use,

is capable of supplying linearly polarized light less absorbable by a polarizing plate and of thus improving brightness, is less apt to pose the problem of coloration, and is applicable also to reflection type liquid-crystal displays and the like. Another object of the present invention is to provide an optical element and a liquid-crystal display each employing the light diffusing plate.

A light diffusing plate of the present invention comprises a birefringent film containing dispersed therein minute regions differing from the birefringent film in birefringent characteristics. The minute regions comprise a thermoplastic liquid-crystal polymer. The difference in refractive index between the birefringent film and the minute regions in a direction perpendicular to the axis direction in which a linearly polarized light has a maximum transmittance, Δn^1, is 0.03 or larger and that in said axis direction, Δn^2, is not larger than 80% of the Δn^1.

The minute regions are preferably formed of a thermoplastic branched liquid-crystal polymer having side chains each containing a segment represented by general formula (I): -Y-Z-, wherein Y is one of a polymethylene chain, a polyoxymethylene chain and a polyoxyethylene chain branching from the main chain and Z is a para-substituted cyclic compound.

An optical element of the present invention comprises a multilayer structure of the above light diffusing plate and at least either of a polarizing plate and a phase plate.

A liquid-crystal display of the present invention comprises a liquid-crystal cell and, disposed on one or each side thereof, either the above light diffusing plate or the above optical element.

In the light diffusing plate in the present invention, the minute regions and the matrix dispersedly containing the same each is made of a polymeric material. Consequently, the light diffusing plate not only is excellent in raw-material handleability and easily producible but has excellent stability of optical functions and excellent suitability for practical use due to the thermal and chemical stability of those materials. Furthermore, in the axis direction (Δn^2 direction) in which a linearly polarized light has a maximum transmittance, the linearly polarized light passes through the diffusing plate while satisfactorily retaining its polarized state. In directions (Δn^1 directions) perpendicular to the Δn^2 direction, the linearly polarized light is scattered based on the difference in refractive index Δn^1 between the birefringent film and the minute regions, whereby the polarized state is diminished or eliminated.

Consequently, by disposing the light diffusing plate and a polarizing plate so that the transmission axis of the polarizing plate is parallel to the Δn^2 direction, the Δn^2 direction-transmittable, linearly polarized light efficiently passes through the polarizing plate and the Δn^1 direction-transmittable, linearly polarized light is scattered. As a result, the

polarization direction is changed, and linearly polarized light components containing Δn^2 direction-transmittable ones pass through the polarizing plate.

The above constitution therefore brings about an increase in the amount of linearly polarized light passing through the polarizing plate, and this effect functions like the reduction of absorption loss to attain an improvement in the brightness of transmission type liquid-crystal displays or the like. Furthermore, the above constitution is less apt to pose the problem of coloration caused by large wavelength dependence such as that of cholesteric liquid crystals, and can be easily applied also to reflection type liquid-crystal displays. Thus, a liquid-crystal display excellent in brightness and perceptibility can be obtained at low cost.

Features and advantages of the invention will become understood from the following detailed description of the preferred embodiments described in conjunction with the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

Fig. 1 is a sectional view of one embodiment of the light diffusing plate;

Fig. 2 is a sectional view of another embodiment of the light diffusing plate;

Fig. 3 is a sectional view of one embodiment of the optical element;

Fig. 4 is a sectional view of one embodiment of the liquid-crystal display; and

Fig. 5 is a sectional view of another embodiment of the liquid-crystal display.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A light diffusing plate of the present invention comprises a birefringent film containing dispersed therein minute regions differing from the birefringent film in birefringent characteristics. The minute regions comprise a thermoplastic liquid-crystal polymer. The difference in refractive index between the birefringent film and the minute regions in a direction perpendicular to the axis direction in which a linearly polarized light has a maximum transmittance, Δn^1, is 0.03 or larger and that in the axis direction, Δn^2, is not larger than 80% of the Δn^1. The minute regions may be formed of a thermoplastic branched liquid-crystal polymer having side chains each containing a segment represented by general formula (I): -Y-Z-, wherein Y is one of a polymethylene chain, a polyoxymethylene chain and a polyoxyethylene chain branching from the main chain and Z is a para-substituted cyclic compound.

Embodiments of the light diffusing plate according to the present invention are shown in Figs. 1 and 2. Numeral 1 denotes

a light diffusing plate and 11, 13, 15, and 17 each denotes a birefringent film dispersedly containing minute regions e which differ from the film in birefringent characteristics. Numerals 12, 14, and 16 each denotes an adhesive layer, 2 an adhesive layer which is a pressure-sensitive adhesive layer for bonding to an adherend, and 21 a separator provisionally covering the pressure-sensitive adhesive layer.

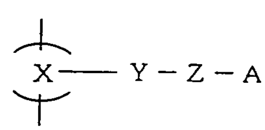
For forming the birefringent film dispersedly containing minute regions differing from the film in birefringent characteristics, a suitable method can be used. For example, one or more polymers serving as a matrix and one or more thermoplastic liquid-crystal polymers described above serving as minute regions are used in such a combination that a film of a mixture thereof comes to have regions differing from the matrix in birefringent characteristics through an appropriate orientation treatment, e.g., stretching, to form an oriented film.

As the matrix polymers, suitable transparent polymers can be used without particular limitations. Examples thereof include polyester polymers such as poly(ethylene terephthalate) and poly(ethylene naphthalate), styrene polymers such as polystyrene and acrylonitrile/styrene copolymers (AS resins), olefin polymers such as polyethylene, polypropylene, polyolefins having cyclic or norbornene structures, and ethylene/propylene copolymers, carbonate polymers, acrylic polymers such as poly(methyl methacrylate), vinyl chloride polymers, cellulosic

polymers such as cellulose diacetate and cellulose triacetate, amide polymers such as nylons and aromatic polyamides, imide polymers, sulfone polymers, polyethersulfone polymers, polyetheretherketone polymers, poly(phenylene sulfide) polymers, vinyl alcohol polymers, vinylidene chloride polymers, vinyl butyral polymers, acrylate polymers, polyoxymethylene polymers, and blends of these.

On the other hand, the thermoplastic liquid-crystal polymers of the minute regions may be selected from either branched type liquid-crystal polymers or main chain type liquid-crystal polymers. The thermoplastic branched liquid-crystal polymers are selected from thermoplastic liquid-crystal polymers having side chains each containing a segment represented by general formula (I): -Y-Z-, wherein Y is one of a polymethylene chain, a polyoxymethylene chain and a polyoxyethylene chain branching from the main chain and Z is a para-substituted cyclic compound. Consequently, examples of the branched liquid-crystal polymers include polymers having segments which each is a monomer unit represented by the following general formula (II).

General Formula (II):



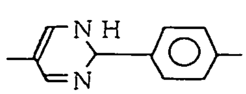
In the above general formula, Y is a flexible spacer group,

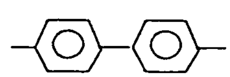
which is one of a polymethylene chain [$-(CH_2)_n-$], a polyoxymethylene chain [$-(CH_2O)_m-$], and polyoxyethylene chain [$-(CH_2CH_2O)_m-$]. In these chains, n and m, which each indicates the number of repetitions, can be suitably determined according to, for example, the chemical structure of the mesogenic group Z bonded thereto. In general, n is from 0 to 20, preferably from 2 to 12, and m is from 0 to 10, preferably from 1 to 4.

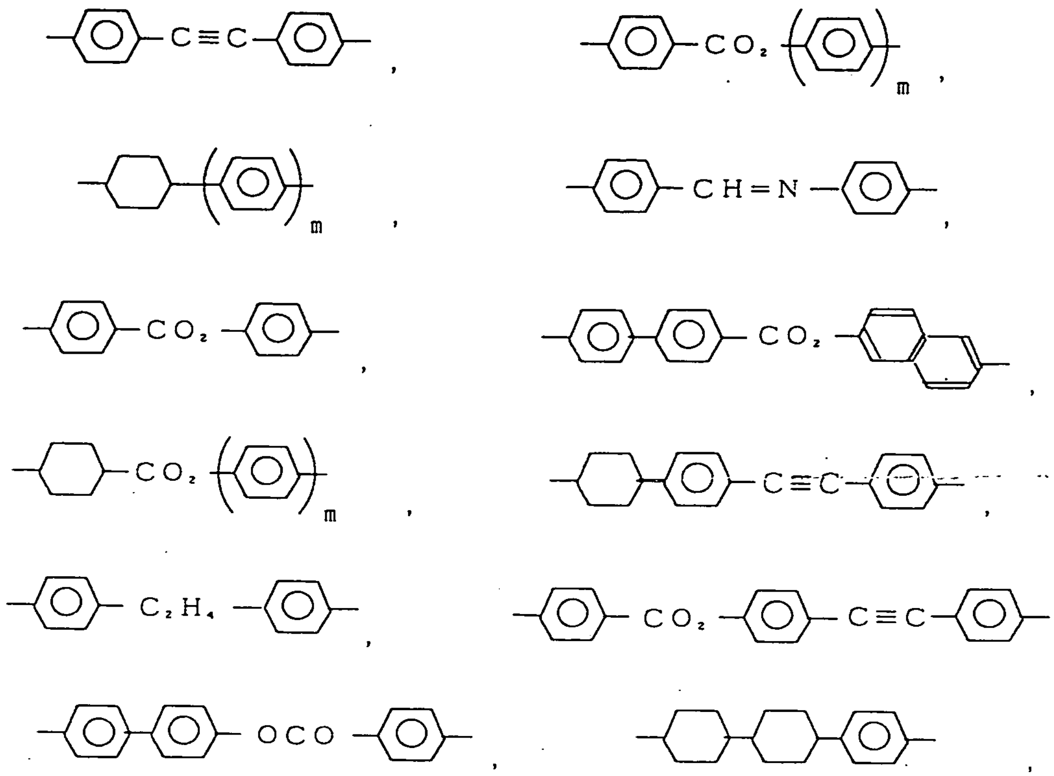
From the standpoint of forming a birefringent film while regulating refractive index and from other standpoints, preferred examples of the spacer group Y include ethylene, propylene, butylene, pentylene, hexylene, octylene, decylene, undecylene, dodecylene, octadecylene, ethoxyethylene, and methoxybutylene.

On the other hand, Z is a para-substituted cyclic compound serving as a mesogenic group imparting the property of undergoing liquid-crystalline orientation. Examples thereof include compounds having a para-substituted, aromatic or cyclohexyl unit such as the azomethine, azo, azoxy, ester, tolan, phenyl, biphenyl, phenylcyclohexyl, or bicyclohexyl type.

Preferred examples of the para-substituted cyclic compound Z, from the standpoint of forming a birefringent film while regulating refractive index and from other standpoints, include those represented by the following chemical formulae.

,

,



In the monomer unit represented by general formula (II), the spacer group Y and the mesogenic group Z may be bonded to each other through an ether bond, -O-. Furthermore, in the phenyl group(s) contained in the para-substituted cyclic compound, one or two hydrogen atoms may have been replaced with a halogen. In this case, the halogen is preferably chlorine or fluorine.

In general formula (II), X is a backbone group constituting the main chain of the liquid-crystal polymer. In the present invention, the backbone group may contain appropriate

connecting groups such as, e.g., linear, branched, or cyclic groups. Examples thereof include polyacrylates, polymethacrylates, poly(α-haloacrylate)s, poly(α-cyanoacrylate)s, polyacrylamides, polyacrylonitriles, polymethacrylonitriles, polyamides, polyesters, polyurethanes, polyethers, polyimides, and polysiloxanes.

The terminal substituent A as the para-substituent of the para-substituted cyclic compound may be an appropriate substituent such as, e.g., a cyano group, an alkyl group, an alkenyl group, an alkoxy group, an oxaalkyl group, a halogen, or an alkyl, alkoxy, or alkenyl group in which one or more of the hydrogen atoms have been replaced with fluorine or chlorine atoms. Consequently, the branched liquid-crystal polymer may be a polymer which is thermoplastic and, at room temperature or elevated temperatures, undergoes appropriate orientation, i.e., comes into a nematic or smectic phase. The liquid-crystal polymer may be a homopolymer made up of monomer units represented by general formula (II), or may be a copolymer containing these monomer units.

The matrix polymer and branched liquid-crystal polymer described above are preferably used in such a combination as to undergo phase separation, from the standpoint of the even distribution of minute regions in the birefringent film to be obtained and from other standpoints. The distribution of minute regions can be regulated by selecting a suitable combination

having a given degree of compatibility. Phase separation can, for example, be accomplished by a method in which incompatible materials are dissolved in a solvent to prepare a solution thereof or by a method in which incompatible materials are mixed together with heating and melting.

In the case of forming a birefringent film through the aforementioned stretching/orientation treatment, the stretching can be conducted at any desired temperature in any desired stretch ratio to form the target birefringent film. The aforementioned polymers include anisotropic polymers which are classified as positive or negative polymers by the change in stretch-direction refractive index through stretching. In the present invention, however, either of such positive and negative, anisotropic polymers can be used.

The film to be oriented can be obtained by an appropriate technique such as, e.g., casting, extrusion molding, injection molding, rolling, or flow casting. It is also possible to obtain the film by spreading a monomer mixture and polymerizing the spread mixture by heating, irradiation with, e.g., ultraviolet, etc.

From the standpoint of obtaining a birefringent film containing highly evenly distributed minute regions and from other standpoints, a preferred method is to use a solution of a mixture of a matrix polymer and a branched liquid-crystal polymer in a solvent to form a film therefrom through casting, flow casting, etc. In this case, the size and distribution of minute regions

can be regulated by changing the kind of the solvent, viscosity of the polymer mixture solution, rate of the drying of the spread polymer mixture solution layer, etc. For example, an advantageous technique for reducing the area of each of minute regions is, for example, to use a polymer mixture solution having a reduced viscosity or to dry the spread polymer mixture solution layer at an increased rate.

Delt. a1

~~The thickness of the film to be oriented can be suitably determined. However, from the standpoint of suitability for orientation and from other standpoints, the thickness thereof is generally from 1 μm to 3 m, preferably from 5 μm to 1 mm, more preferably from 10 to 500 μm. In forming the film, appropriate additives can be incorporated, such as, e.g., a dispersant, surfactant, ultraviolet absorber, color tone regulator, flame retardant, release agent, and antioxidant.~~

Orientation can be accomplished by conducting one or more appropriate treatments capable of regulating refractive index through orientation. Examples of the orientation treatments include: stretching treatments such as uni- or biaxial stretching, successive biaxial stretching, and stretching along a Z axis; a rolling technique; a technique in which an electric or magnetic field is applied to the film kept at a temperature not lower than the glass transition or liquid-crystal transition point thereof and the film is then rapidly cooled to fix the orientation; a technique in which polymer molecules are oriented during film

formation by means of flow orientation; and a technique in which a liquid-crystal polymer is caused to orient by itself based on the slight orientation of an isotropic polymer. Consequently, the birefringent film obtained may be a stretched film or unstretched film. Although a stretched film can be obtained from a brittle polymer, it is especially preferably obtained from a highly stretchable polymer.

The birefringent film used in the present invention has been regulated so that the difference in refractive index between the birefringent film and the minute regions in a direction perpendicular to the axis direction in which a linearly polarized light has a maximum transmittance, Δn^1, is 0.03 or larger and that in said axis direction, Δn^2, is not larger than 80% of the Δn^1. By regulating the birefringent film so as to have such differences in refractive index, the film can have the excellent ability to scatter light in Δn^1 directions and to maintain a polarized state in the Δn^2 direction.

From the standpoints of scattering properties and of changing or eliminating a polarized state based on the scattering and from other standpoints, it is preferred that the difference in refractive index in a Δn^1 direction, Δn^1, be a moderately large value. Specifically, Δn^1 is preferably from 0.04 to 1, more preferably from 0.045 to 0.5. On the other hand, from the standpoint of maintaining a polarized state and from other standpoints, it is preferred that the difference in refractive

index in the Δn^2 direction, Δn^2, be as small as possible. Specifically, Δn^2 is preferably 0.03 or smaller, more preferably 0.02 or smaller, most preferably 0.01 or smaller.

Consequently, the orientation described above can be regarded as a treatment for increasing the difference in refractive index in a Δn^1 direction between the birefringent film and the minute regions, or as a treatment for reducing the difference therebetween in refractive index in the Δn^2 direction, or as a treatment for accomplishing both.

In the birefringent film, the minute regions are preferably dispersed and distributed as evenly as possible from the standpoints of homogeneity in the aforementioned scattering effect, etc. The size of the minute regions, especially the length thereof in Δn^1 directions, which are directions of scattering, relates to backward scattering (reflection) and wavelength dependence.

On the other hand, from the standpoint of inducing and enhancing backward scattering, it is preferred to regulate the Δn^1-direction diameter of the minute regions to a size which causes Rayleigh scattering, that is, to a size sufficiently smaller than the wavelengths of the light to be used. From the standpoint of diminishing the wavelength dependence of scattered light, the Δn^1 direction size of the minute regions is preferably as large as possible, although this adversely influences the above-described inhibition of backward scattering.

From the standpoints of the above-described inhibition of backward scattering and wavelength dependence, etc. and, hence, from the standpoints of improving the efficiency of light utilization, preventing coloration due to wavelength dependence, preventing the minute regions from being visually perceived to impair bright displaying, and attaining satisfactory film-forming properties and film strength, etc., the size of the minute regions in terms of the Δn^1 direction length thereof is preferably from 0.05 to 500 μm, more preferably from 0.1 to 250 μm, most preferably from 1 to 100 μm. The Δn^2 direction length of the minute regions, which are present usually as domains in the birefringent film, is not particularly limited.

As described above, the birefringent film for use in the present invention has anisotropy in birefringent characteristics between a Δn^1 direction and the Δn^2 direction so that a linearly polarized light can be controlled according to vibration planes. Although the proportion of the minute regions in the birefringent film can be suitably determined from the standpoints of Δn^1-direction scattering, etc., it is generally from 0.1 to 70%, preferably from 0.5 to 50%, more preferably from 1 to 30%, from the standpoint of further attaining a satisfactory film strength, etc.

The light diffusing plate according to the present invention may consist of only one birefringent film 1 containing dispersed therein minute regions differing from the film in

birefringent characteristics, as shown in Fig. 1. Alternatively, it may comprise such birefringent films 11, 13, 15, and 17 superposed on each other, as shown in Fig. 2. This film superposition can bring about a synergistic scattering effect higher than the scattering effect expected from the thickness increase. Use of such superposed birefringent films in combination with a polarizing plate is especially advantageous in that the light transmitted by the polarizing plate can be intensified by more than the amount corresponding to the reflection loss caused by the film superposition.

The superposed structure may be one obtained by superposing birefringent films while positioning each film at any desired angle with respect to the Δn^1 or Δn^2 direction. However, from the standpoints of enhancing the scattering effect, etc., it is preferred to superpose the films in such a manner that the Δn^1 directions for any film layer are parallel to those for the adjacent layer(s). The number of superposed birefringent films can be an appropriate number of 2 or larger.

The birefringent films to be superposed may have the same or different values of Δn^1 or Δn^2. With respect to the parallelism in, e.g., Δn^1 direction between adjacent layers, fluctuations of parallelism caused by operational errors are allowable, although a higher degree of parallelism is preferred. In the case of a layer which has fluctuations in, e.g., Δn^1 direction, the parallelism is based on the average of these.

The birefringent films in the superposed structure may be in a merely stacked state. It is, however, preferred that the birefringent films have been bonded to each other through an adhesive layer or the like from the standpoints of preventing film shifting in, e.g., Δn^1 directions and preventing foreign substances from coming into each interface and from other standpoints. For the bonding, an appropriate adhesive can be used, such as a hot-melt or pressure-sensitive adhesive. From the standpoint of diminishing reflection loss, an adhesive layer whose refractive index is as close as possible to that of the birefringent films is preferred. It is also possible to bond the birefringent films with the same polymer as that constituting either the films or the minute regions contained therein.

The light diffusing plate according to the present invention can be used in various applications because it has the property of transmitting and scattering linearly polarized light. Examples of the applications include a polarizing amplifier plate, color regulator plate, polarizing separator plate, display control plate, liquid-crystal display screen, and polarizer aid plate.

The polarizing amplifier plate is a device comprising a light diffusing plate which is highly effective in light scattering but is reduced in backward scattering and which is disposed on the light incidence side of a polarizing plate. This device is intended to change the direction of polarization based

on the scattering properties of the light diffusing plate (Δn^1 directions) to thereby increase the amount of Δn^2 direction-transmittable, linearly polarized light and thus improve the degree of polarization or the efficiency of light utilization.

The color regulator plate is a device which comprises a light diffusing plate having large wavelength dependence to be disposed on the front side of a reflection type liquid-crystal display or the like having a low blue light transmittance, and is intended to amplify polarized light in the blue region to thereby prevent display yellowing, etc. Namely, the color regulator plate is used mainly for regulating a color balance.

The polarizing separator plate is a device comprising a light diffusing plate showing scattering similar to Rayleigh scattering. The light diffusing plate is disposed between a light guide plate and a polarizing plate, whereby the backward scattered light is eliminated through polarization and then caused to strike again on the polarizing plate through, e.g., the reflecting layer on the bottom of the light guide plate. Namely, the polarizing separator plate is intended to increase the amount of Δn^2 direction-transmittable, linearly polarized light and thus improve the degree of polarization or the efficiency of light utilization.

The display control plate is a device comprising a light diffusing plate showing reduced backward scattering and having high haze anisotropy. The light diffusing plate is disposed

between a liquid-crystal cell and a viewing-side polarizing plate to thereby scatter the light corresponding to white displaying and transmit the light corresponding to black displaying. Namely, the display control plate is intended to improve contrast and image clearness. The liquid-crystal display screen is a device comprising a light diffusing plate as a screen which selectively transmits given components of incident light as linearly polarized light. Namely, the liquid-crystal display screen is intended to improve contrast. The polarizer aid plate is a device comprising a light diffusing plate which has high haze anisotropy and is to be disposed between a polarizing plate and a light source in a display. This device is intended to inhibit the light absorbable by the polarizing plate from striking thereon and to thereby prevent the polarizing plate from heating up.

Consequently, the light diffusing plate according to the present invention may be subjected to practical use as an optical element comprising, for example, a multilayer structure in which the light diffusing plate is disposed on one or each side of one or more appropriate optical parts, e.g., a polarizing plate and/or phase plate. An example of this optical element is shown in Fig. 3, wherein numeral 3 denotes an optical part. In this multilayer structure, the components may be in a merely stacked state or may have been bonded to each other through an adhesive layer or the like. With respect to this adhesive layer, the same explanation can be given as in the superposition of birefringent films.

There are no particular limitations on the optical parts which may be optionally superposed, and appropriate ones may be used. Examples thereof include a polarizing plate, a phase plate, a backlight such as a light guide plate, a reflector plate, a polarizing separator plate comprising, e.g., a multilayered film, and a liquid-crystal cell. Such optical parts to be superposed, including a polarizing plate and a phase plate, may be any of various types.

Specifically, examples of the polarizing plate include absorption type, reflection type, and scattering type polarizers, while examples of the phase plate include a quarter-wavelength plate, a half-wavelength plate, a phase plate comprising a uni- or biaxially or otherwise stretched film, one comprising a film which has undergone inclined orientation, i.e., which has undergone molecular orientation also in the thickness direction, one comprising a liquid-crystal polymer, one in which a phase difference caused by a viewing angle or birefringence is compensated for, and one comprising two or more of these phase plates superposed on each other. In the present invention, any of these can be used.

Specific examples of the polarizing plate include absorption type polarizing plates obtained by adsorbing iodine or a dichroic substance, e.g., a dichroic dye, onto a hydrophilic polymer film, such as a poly(vinyl alcohol) film, a film of poly(vinyl alcohol) which has undergone partial conversion into

formal, or a film of a partially saponified ethylene/vinyl acetate copolymer, and then stretching the film. Examples thereof further include oriented polyene films such as a film of dehydrated poly(vinyl alcohol) and a film of dehydrochlorinated poly(vinyl chloride).

Examples of the polarizing plate still further include a polarizing plate comprising any of the aforementioned polarizing films and a transparent protective layer formed on one or each side thereof for the purpose of protection against water, etc. The protective layer may be, for example, a coating layer of a plastic or a laminated film layer. The transparent protective layer may contain fine transparent particles having an average particle diameter of from 0.5 to 20 μm so as to impart fine roughness to the surface of the above polarizing plate. Examples of such fine transparent particles include fine inorganic particles which may be electroconductive, such as silica, alumina, titania, zirconia, tin oxide, indium oxide, cadmium oxide, and antimony oxide particles, and fine organic particles made of a crosslinked or uncrosslinked polymer.

On the other hand, specific examples of the phase plate include stretched films made of any of the polymers enumerated hereinabove with regard to the birefringent film or made of a liquid-crystal polymer especially of the twisted alignment type. Furthermore, examples of the light guide plate include one which comprises a transparent resin plate and, disposed by a side edge

thereof, either a line light source such as a (cold or hot) cathode tube or a light source such as one or more light-emitting diodes or ELs and has such a constitution that the light transmitted by the resin plate is emitted from one side of the plate through diffusion, reflection, diffraction, interference, etc.

In fabricating an optical element containing a light guide plate, use can be made of a suitable combination of the light guide plate with one or more auxiliary means disposed according to need in predetermined positions, e.g., on the upper or lower surface of the light guide plate or at a side edge thereof. Examples of such auxiliary means include a prism array layer which comprises a prism sheet or the like and is used for controlling the direction of light emission, a diffusing plate for obtaining even illumination, and a light source holder for introducing the light emitted by a line light source into a side edge of the light guide plate.

The multilayer structure constituting the optical element according to the present invention may contain one optical part or may contain one or more optical parts. The multilayer structure may also be one containing two or more optical parts of the same kind, e.g., phase plates. In this case, these optical parts of the same kind, e.g., phase plates, may have the same or different properties. One or more light diffusing plates may be contained in the optical element. These light diffusing plates may be disposed in appropriate positions outside or within the

multilayer structure, e.g., on one or each outer side of the multilayer structure or on one or each side of an optical part contained in the multilayer structure.

In the case where the optical element contains a polarizing plate, the light diffusing plate is preferably disposed in such a position that the Δn^2 direction for the light diffusing plate is parallel to the transmission axis of the polarizing plate, from the standpoint of effectively utilizing the transmitting/scattering properties of the light diffusing plate and from other standpoints. With respect to the above parallelism, the same explanation can be given as in the case of superposing birefringent films described hereinabove. In the optical element having the above constitution, the linearly polarized light absorbable by the polarizing plate is scattered by the light diffusing plate in Δn^1 directions. This optical element can hence be suitable for use as, e.g., the polarizing amplifier plate, polarizing separator plate, liquid-crystal display screen, and polarizer aid plate described above.

From the standpoint of improving brightness and contrast and from other standpoints, preferred polarizing plates for use as components of the optical element are those attaining a high degree of polarization, such as the above-described absorption type polarizing plates containing a dichroic substance. Especially preferred among such polarizing plates are those having a light transmittance of 40% or higher and a degree of

polarization of 95.0% or higher, in particular 99% or higher.

Since the light diffusing plate and optical element according to the present invention have the advantages described above, they are suitable for use in a liquid-crystal display. Examples of the liquid-crystal display are shown in Figs. 4 and 5. Numerals 4 and 41 each denotes a polarizing plate, 5 a liquid-crystal cell, 6 a diffusing reflector, 7 a light guide plate, 71 a reflecting layer, 72 a light source, and 8 a light diffusing plate for diffusing display light.

In the example shown in Fig. 4, which is a reflection type liquid-crystal display, the light diffusing plate 1 is disposed on the outer side of the viewing-side polarizing plate 4 so that the Δn^2 direction therefor is parallel to the transmission axis of the polarizing plate. On the other hand, in the example shown in Fig. 5, which is a transmission type liquid-crystal display, the light diffusing plate 1 is interposed between the light guide plate 7 constituting a backlight and the back-side polarizing plate 4 so that the Δn^2 direction therefor is parallel to the transmission axis of the polarizing plate.

In general, a liquid-crystal display is fabricated, for example, by suitably assembling components including a polarizing plate, a liquid-crystal cell, a reflector or backlight, and optional optical parts and integrating a driving circuit into the assemblage. In the present invention, a liquid-crystal display can be fabricated according to such a conventional procedure

without particular limitations, except that the light diffusing plate or the optical element described above is used. Consequently, appropriate optical parts can be suitably disposed in fabricating the liquid-crystal display. For example, a light diffusing plate, anti-glare layer, antireflection film, protective layer, or protective plate may be disposed over a viewing-side polarizing plate. Furthermore, a phase plate for compensation may be interposed, for example, between the liquid-crystal cell and the viewing-side polarizing plate.

The phase plate for compensation is intended, for example, to compensate for the wavelength dependence of birefringence, etc. to thereby improve perceptibility, as described above. This phase plate is disposed, for example, between the liquid-crystal cell and at least one of polarizing plates disposed respectively on the viewing side and on the backlight side. As the above phase plate for compensation, a suitable phase plate such as that described above can be used according to wavelength region, etc. The phase plate for compensation may be composed of two or more layers each serving as a phase plate.

In the liquid-crystal display described above, one or more light diffusing plates or optical elements according to the present invention can be disposed, each as a unit, in appropriate positions on one or each side of the liquid-crystal cell. For example, in a liquid-crystal display wherein the light diffusing plate is oriented so that the Δn^2 direction therefor is parallel

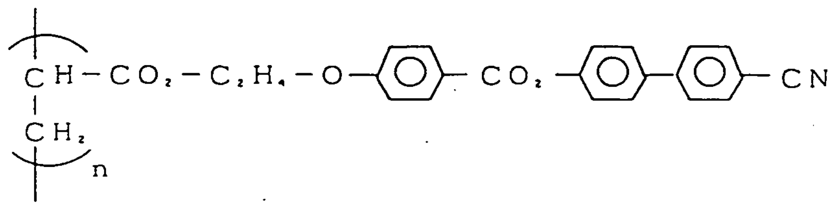
to the transmission axis of a polarizing plate, the light diffusing plate is disposed in one or more appropriate positions where linearly polarized light absorbable by a polarizing plate is desired to be polarized through scattering. Specifically, when the liquid-crystal display is of the reflection type, the light diffusing plate may be disposed on the light incidence side of a polarizing plate, especially one disposed on the viewing side. When the liquid-crystal display is of the transmission type, the light diffusing plate may be disposed in an appropriate position between a back-side polarizing plate and a backlight.

The light diffusing plate to be disposed in any of the positions described above can be used as a multilayered optical element containing the light diffusing plate united with other optical parts or other components. With respect to the liquid-crystal display also, the constituent parts have preferably been united with each other through adhesive layers as in the light diffusing plate according to the present invention, etc.

EXAMPLE 1

A 20 wt% dichloromethane solution containing 900 parts (parts by weight; the same applies hereinafter) of a norbornene resin (Arton, manufactured y JSR Co., Ltd.) was mixed with 100 parts of a liquid-crystal polymer represented by the following formula. This mixture was used to obtain a 100 μm-thick film by casting. This film was stretched at 175°C in a stretch ratio of

3. Thus, a light diffusing plate was obtained which consisted of a birefringent film having a refractive index difference Δn^1 of 0.230 and a refractive index difference Δn^2 of 0.029.



The birefringent film consisted of the norbornene resin as a film base and the liquid-crystal polymer dispersed therein as domains elongated along the stretch direction. The average diameter of these domains was measured through an examination with a polarizing microscope based on coloration by phase difference. As a result, the Δn^1 direction length thereof was found to be about 6 μm.

EXAMPLE 2

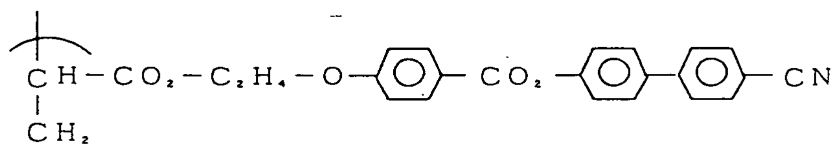
Two birefringent films which were the same as that obtained in Example 1 were superposed and bonded to each other through a 20 μm-thick acrylic pressure-sensitive adhesive layer so that these films coincided with each other in Δn^2 direction. Thus, a light diffusing plate was obtained.

EXAMPLE 3

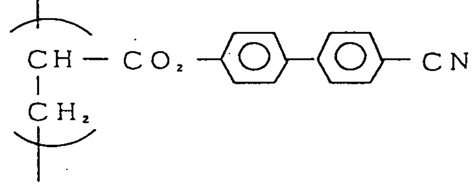
A light diffusing plate was obtained in the same manner as in Example 1, except that a liquid-crystal polymer represented by the following formula was used. The light diffusing plate thus

obtained consisted of a birefringent film having a Δn^1 of 0.180 and a Δn^2 of 0.032. In copolymerization for producing the liquid-crystal polymer, a monomer corresponding to units "a" and one corresponding to units "b" were used in amounts of 45 parts and 55 parts, respectively. The birefringent film consisted of the norbornene resin as a film base and the liquid-crystal polymer dispersed therein as domains elongated along the stretch direction (Δn^1-direction length; about 6 μm).

(a)

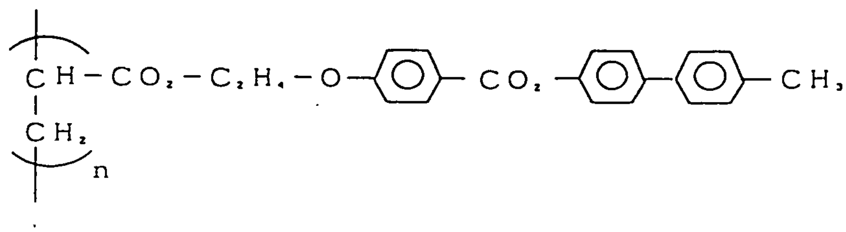


(b)



EXAMPLE 4

A light diffusing plate was obtained in the same manner as in Example 1, except that a liquid-crystal polymer represented by the following formula was used. The light diffusing plate thus obtained consisted of a birefringent film having a Δn^1 of 0.150 and a Δn^2 of 0.033. The birefringent film consisted of the norbornene resin as a film base and the liquid-crystal polymer dispersed therein as domains elongated along the stretch direction (Δn^1-direction length; about 6 μm).



EXAMPLE 5

The light diffusing plate obtained in Example 1 was bonded to a commercial polarizing plate having a total light transmittance of 41% and a degree of transmitted-light polarization of 99% with an acrylic pressure-sensitive adhesive layer so that the Δn^2 direction coincided with the transmission axis. Thus, an optical element was obtained.

EXAMPLE 6

An optical element was obtained in the same manner as in Example 5, except that the light diffusing plate obtained in Example 2 was used.

EXAMPLE 7

An optical element was obtained in the same manner as in Example 5, except that the light diffusing plate obtained in Example 3 was used.

EXAMPLE 8

An optical element was obtained in the same manner as in Example 5, except that the light diffusing plate obtained in Example 4 was used.

EXAMPLE 9

A diffusing reflector plate, a polarizing plate, a TN liquid-crystal cell, and the optical element obtained in Example 5 were successively superposed and bonded in this order through an acrylic pressure-sensitive adhesive layer in such a manner that the polarizing plate of the optical element faced the cell. Thus, a reflection type liquid-crystal display having the constitution shown in Fig. 4 was obtained. Each polarizing plate was disposed so that the direction of the transmission axis therefor coincided with the direction of rubbing on that side of the liquid-crystal cell which faced the polarizing plate.

EVALUATION TEST 1

The light diffusing plates and optical elements obtained in Examples were examined for total light transmittance, diffuse transmittance, and haze with a Poick integrating sphere hazeometer according to ASTM D1003-61. The degree of polarization of the whole transmitted light was also determined. The results obtained are shown in the following table. In the examination of each optical element, light was caused to strike thereon from the polarizing plate side and from the light diffusing plate side. The data obtained in the case of incidence from the light diffusing plate side are given in parentheses.

	Total light transmittance (%)	Degree of polarization (%)	Diffuse transmittance (%)	Haze
Example 1	91	50	55	60
Example 2	89	60	80	86

Example 3	90	48	48	53
Example 4	90	46	46	51
Example 5	41 (51)	99	4 (14)	10 (27)
Example 6	41 (52)	99	7 (16)	18 (31)
Example 7	40 (47)	99	8 (12)	20 (26)
Example 8	40 (44)	99	10 (13)	25 (30)

The results given in the table show the following. Light diffusing plates functioning to polarize had been obtained (Examples 1 and 2). The superposition of birefringent films caused a reflection loss and hence resulted in a decrease in total light transmittance (Examples 1 and 2). However, when the superposed birefringent films were combined with a polarizing plate, the total light transmittance was increased by more than the amount corresponding to the reflection loss. Namely, the superposed birefringent films were effective in scattering the linearly polarized light absorbable by the polarizing plate and in thus greatly increasing the amount of the linearly polarized light transmittable by the polarizing plate (Examples 5 and 6). Furthermore, a comparison in Examples 5 and 6 between the examinations where different incidence directions were used shows that the total light transmittance for the polarizing plate alone (41%) was greatly improved by causing the light to strike on the optical element from the light diffusing plate side.

EVALUATION TEST 2

The liquid-crystal display obtained in Example 9 was examined for brightness in a displaying state with a luminance meter. As a result, the display was ascertained to have a greatly

improved brightness as compared with the case where a polarizing plate alone was used.

While the presently preferred embodiment of the present invention has been shown and described, it is to be understood that the disclosure is for the purpose of illustration and that various changes and modification may be made without departing from the scope of the invention as set forth in the appended claims.